Delay of Reliable Multicast Protocols in Wireless Networks

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Abstract: Wireless Mesh Network (WMN) plays important roles towards the next generation wireless networking. It is a key technology to support wireless multi-hop networks. Due to dynamic routing nature of WMNs, the optimization of routing protocol is most critical task. Our work consists on the study and the analysis of the performances of two reliable multicast protocols based on active networks: AMRHy(Active Dynamic Replier Reliable Multicast) and DyRAM(Active Multicast Reliable Hybrid). This analysis will allow us to show the contribution of the combination of the class receiver-initiated and sender- initiated in solving the reliability problem involving the active routers.

Keywords: reliability, Active networks, Sender- initiated, Receiver-initiated, DyRAM, AMRHy, loss recovery, Delivery time

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1. Introduction

The increasing number of Internet users in the last decades led to the use of devices and applications with a huge amount of network resources in order to satisfy end users requirements. However, the performance of the traditional networks types which may be wired or wireless is not satisfactory enough: the cost is very high or the throughput is not sufficient. Wireless Mesh Network (WMN) is one of new emerging key technology in wirelessnetwork that provide adaptive, flexible and cost effective structural network [12]. The WMN is built on routers that works by transferring packets from one node to destinationnode that is out of range of sender node. Due to flexible and adaptive infrastructure, the routers act as multi-hope access point to the internet for mesh clients' nodes. Thesemesh client nodes also connect with the other nodes to make whole network adaptive. Various devices such as mobiles, laptops and PDAs can access the network throughWMN at anytime and anywhere. The adaptive and flexiblenature of WMN makes its integration in any network easy,such as cellular, wireless, WiMax and WiFi networks [13].Due to large number of nodes involvement in communication routing is the most important issue in this network. Routing is a mechanism through which the packet can transfer from source to ultimate destination. Due to self-configured and self-awareness features of WMNs, it is expected that in WMN the nodes can decide best path automatically. Efficient communication in WMN depends on these routing decisions.

In this study, we discuss the contribution of the combination of sender-initiated and receiver-initiated classes in solving the recovery latency problem involving routers capable of executing personalized services according to the received packets. To do this, we present a comparative study between two reliable multicast protocols: Protocol DyRAM (Active Dynamic Replier Reliable Multicast) [8], which represents the protocols of the class receiver-initiated, and the protocol AMRHy (Active Multicast Reliable Hybrid) [1] that combines both sender-initiated classes and receiver-initiated. Our study will show the impact of the depth of the multicast tree, the group size and the probability of loss on the performance of both protocols. The remainder of this paper is organized as follows: related works are discussed in Section 2. Section 3 describes the network model and basic definitions and assumptions. Section 4 describes the behavior of the two analyzed protocols giving the recovery diagram of each entity. Section 5 presents the results of the analytical analysis, and the last section concludes thispaper and sets directions for future works.

2. State-of-the-art

The comparative study between multicast protocols have been studied in many context, the first comparative analysis between the sender-initiated and receiver-initiated classes of reliable multicast protocols was made by Pingali et al [9]. This analysis showed that the protocols of the receiver-initiated class are more scalable than sender-initiated class because the maximum throughput of sender-initiated class depends on the number of receivers, whereas it is not the case in the receiver-initiated class. Levine et al [5] have extended this work to that the organization of all the receivers in a hierarchical structure ensures scalability and enhance performance. They also showed that the protocols using the receiver-initiated class cannot guarantee the reliability in an environment with limited caches. Another comparative analysis of sender-initiated and receiver-initiated classes was presented by Maihöfer and Rothermel [7]. Their analysis showed that the protocols of the receiver-initiated class achieve better scalability but those of the sender-initiated class ensures reduced latencies. On the other hand, the efficiency of bandwidth has been subject of several analytical studies. The analysis of generic reliable multicast protocols was made by Kasera et al [4] and has shown that local recovery approaches provide a significant performance of bandwidth and delay consumption. In [6], Maihöfer presented an analytical evaluation of the bandwidth of generic reliable multicast protocols and has shown that hierarchical approaches provide not only high throughput but also consume less bandwidth. This work was extended by comparing the class receiver-initiated and the combination of classes the sender-initiated and receiver-initiated by Derdouri et al [2]. The study focused on the bandwidth consumption and the throughput and showed that the combination of the classes is more scalable and consumes less bandwidth than receiver-initiated class especially when the network is unreliable.

In this paper we extend this comparison to the recovery latency considering an unreliable backbone where the data packets losses often occurs within thisbackbone, unlike the previous analysis made on the reliable multicast that considers the backbone as being reliable.

3. Environment and Network Model

3.1 Environment

WMN is a dynamic self-organized, self-configured and self-maintained, multi hoped packet network. It consists of number of nodes that are connected through wireless media and arranged in a mesh topology. These nodes can automatically link and leave the network at anytime.WMN provides services at anywhere and anytime even if no fixed infrastructure exists at that place. The nodes in WMN can be act as a both router and a host, but generally it is categories as a two types of nodes: Mesh clients (MCs) and Mesh routers (MRs). MRsare fixed and build the backbone infrastructure of thenetwork where MCs are usually mobile and roam among these MRs. These MRs are gateway to internet where MCscan connect to the MRs and other MCs also. The fixed backbone infrastructure of network provides multi- hopping access services to the internet for MCs. The route for packet communication is selected by using certain routing protocols. Mesh solutions have many advantages over traditional wireless networks such as low costs, easy to maintain, large scale deployment, robustness and greater coverage area .

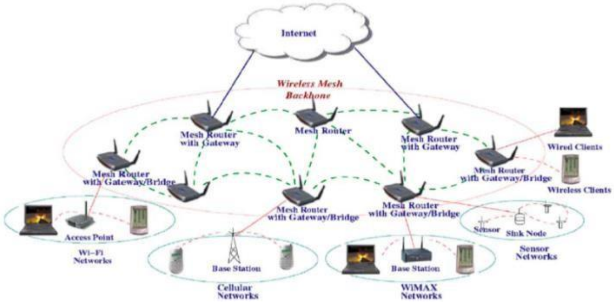

Fig. 1. Example of a mesh network

3.2 Network Model

The network model used for the evaluation of reliable multicast protocols consists on constructing a multicast tree through a wireless mesh network. The root of this tree represents the bridge that connects the Mesh network to the Internet; the leaves of this tree are the Mesh Clients. The intermediate nodes of the tree represent the Mesh Routers that are located at different levels to the source. In the context of wireless mesh networks, all routers in the multicast tree are considered of being active and can perform customized treatments on packets passing through them (data packets or acknowledgment (NAKs and ACKs)).

The first active service supported by active routers is the data packets cache for a fixed period to ensure recovery of lost data packets locally. The second active service supported by the active routers is the aggregation and suppression of identical NAKs and ACKs. The third active service consists in the subcast functionality, where repair packets are sent only to the affected receivers avoiding the problem of receptors exposure. The fourth active service is the dynamic election of a replier providing a local loss recovery and ensuring a load balanced on the subgroup. To assess the impact of the combination of the two classes, it is considered that the two protocols **AMRHy** and **DyRAM** benefit of all active services.

For the delay analysis, we consider a network model with multi-level multicast tree. A source diffuses data packets through the tree to R receivers distributed according to the topology N=R/B, the receptors are divided into subgroups of B receptors (R_1, R_2, …, R_B) connected to the source through an active router A_s, wireless link that connects the source to the active router is called source-link. Similarly, the wireless link connecting the active router A_t to each of the receivers is called tail-link (see Figure 2). The wireless links connecting the active routers between them are the backbone links. We consider that the source links, terminals and those of a Backbone respectively have a loss probability P_l.. Therefore, the probability of end to end perceived by a receiver is $P = 1 - (1 - P_l)^h$ where h is the depth of multicast tree. Unlike the analysis made on reliable multicast, we assume that the backbone is not reliable and that data packets can be lost in the Backbone. We suppose initially, that the NAKs (ACKs) are never lost and they follow the same path traced by the data packet in order to benefit from active service.

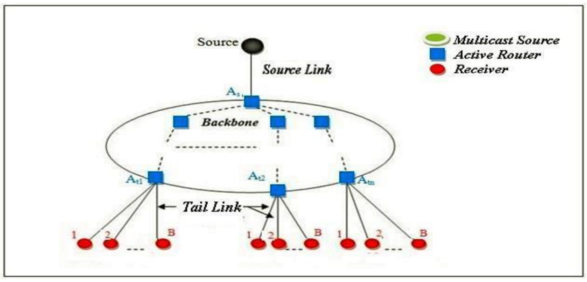

Fig. 2. Network Model

4. Protocol Description

AMRHy and **DyRAM** are two protocols that use active services in routers. Each one adopts a different strategy to solve the problems of scalability. **DyRAM** is based on *receiver-initiated* class in which the responsibility of loss detection is attributed to the receivers. However, the responsibility of loss detection in AMRHy is distributed between the source and receivers by combining the sender-initiated and receiver-initiated classes. In this hybrid approach, the source supports the losses that occur in the source link while receivers care for those that occur in the terminal links.

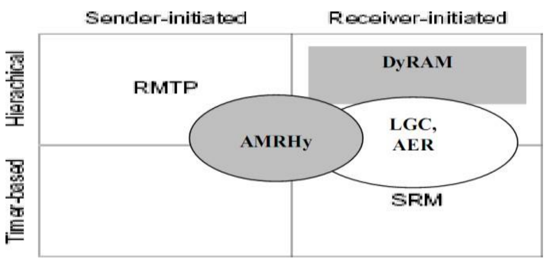

Fig. 3. DyRAM and AMRHy in protocol classification

4.1 Protocol DyRAM

DyRAM is an active reliable multicast protocol, based on the hierarchical approach. It adopts a local recovery scheme based on receiver-initiated class; the receivers are responsible of the losses detection, and possibly the retransmission of the lost data packets. This protocol is distinguished from other reliable multicast protocols by its innovative features:

• For each lost packet, a dynamic election of a replier is performed. It is elected from among the receivers that have correctly received the data packet.

• The Emulation of positive acknowledgments due to the addition of new fields in the headers of the control packet of the protocol.

• The Subcast repair packets only to receivers who actually lost the data packets.

The figures (figure 4 and figure 5) show respectively the recovery policy used by source to recover a lost data packet and the dynamic election of a replier by the active router.

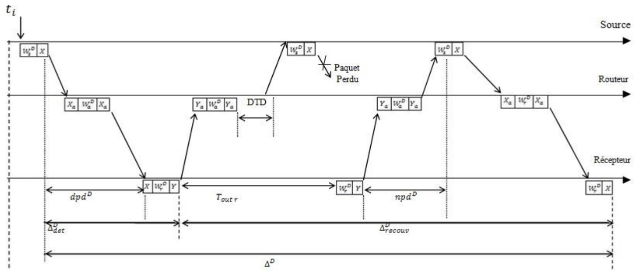

Fig. 4. DyRAM Source recovery

The recovery of the lost packet is done by the source is calculated as the following:

$$E[\Delta^{D}_{recouv\ s}] = \mathbf{NST} + \boldsymbol{DTD} + E[\boldsymbol{npd^D}] + E[\boldsymbol{dpd^D}] + E[W_s^D] + E[W_r^D] + 2E[X] + \frac{(Tout_r + E[W_r^D] + E[Y])p}{(1-p)} \quad (1)$$

Where ***DTD*** is the time for active router to elect a replier , **NST** is the NACK Suppression Timer, $[npd^D]$ *is* the average is required time for a NAK to be received by the source, $E[dpd^D]$ is the average required time for a data packet sent by the source to be received by any receiver. $E\,[W_r^D]$is the average waiting time for a data packet to be arrived to destination , $E[X]$ is the load at the receiver , $p^{j-1}(1 - p)$ is the probability of (j-1) retransmission of the packet until it is correctly received by any receiver . $Tout_r$is the timer at the receiver.

The recovery of the lost packet is done by a dynamic elected replier is calculated as the following:

$$E[\Delta^{D}_{recouv\ r}] = \mathbf{NST} + \boldsymbol{DTD} + E[\boldsymbol{npd^D}] + E[\boldsymbol{dpd^D}] + E[W_r^D] + 2E[X] + (Tout_r + E[W^D] + [Y])p/(1-p) \quad (2)$$

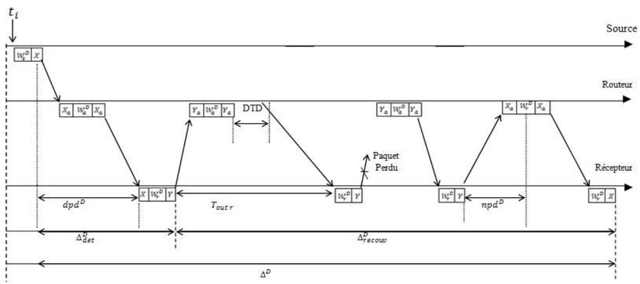

Fig. 5. DyRAM dynamic election of a replier

4.2 Protocol AMRHy

AMRHy overcomes the inconveniences of the "receiver-initiated" class by combining the two classes "sender-initiated" and "receiver-initiated". The combination of these two classes has resulted in the coexistence of positive and negative acknowledgments. The positive acknowledgment is used between the receivers and the source to confirm the correct reception of a data packet by at least one receiver. It also allows the active router:

- To invite the members of his group, having lost the data packet to report the loss before the packet is removed from the cache.
- To inform the members of the group by the address of the dynamically replier elected for future repairs without active services,
- To inform the members of his group, who received the data packet correctly, to make a local suppression of their corresponding ACKs
- Delete the cache of the data packet in question.

The recovery of the lost packet is done by the source is calculated as the following:

$$E[\Delta^{A}_{\text{recouv s}}] = E[dpd^{A}] + E[apd^{A}] + E[W^{A}_{s}] + E[W^{A}_{a}] + 2E[X] + E[W^{A}_{s}] + 2E[Z] + (T_{out})\,p/(1-p) \quad (3)$$

On the other hand, it allows the source to release the transmission buffer associated with the data packet. The negative acknowledgment is used locally between therouter and the active receivers of its group to report the loss of a data packet.

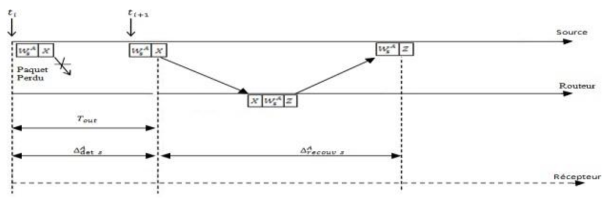

Fig. 6. AMRHy Source recovery

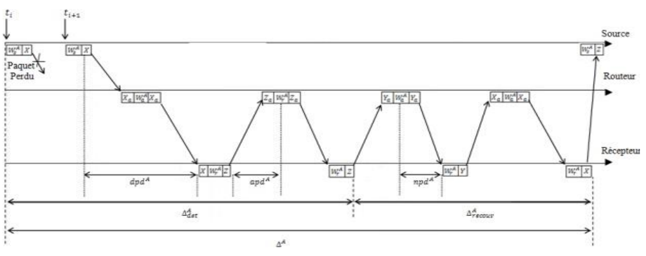

Fig. 7. AMRHy receiver elected as a replier recovery

The recovery of the lost packet is done by the receiver elected as a replier is calculated as the following:

$$E[\Delta^{A}_{\text{recouv r}}] = E[npd^{A}] + E[dpd^{A}] + E[W^{A}_{a}] + E[W^{A}_{r}] + 2E[X] + (T_{out\,r} + E[W^{A}_{r}] + E[Y])\,p/(1-p) \quad (4)$$

5. Experimental Results

In this section, we use the model described before to analyze numerically the two protocols. The study is done according to the overall delay calculated for each protocol. we determine the influence of three parameters: the size of the local group (B), the depth of the backbone (H) and the probability of loss (P) on the delay of losses recovery at the packet level of data. For the numerical evaluation, weadopt the same measures as those taken in [11]:

5.1 Influence of the Size of the Local Group B on the Overall Time

Figure 8 show that the protocol **AMRHy** is more efficient in terms of overall time than the protocol **DyRAM** and this regardless of the increase of the local group B, this is caused by the combination of *the sender-initiated* and *receiver-initiated classes* adopted by **AMRHy** allowing a fair distribution of load between the source, the active routers and receivers. In addition

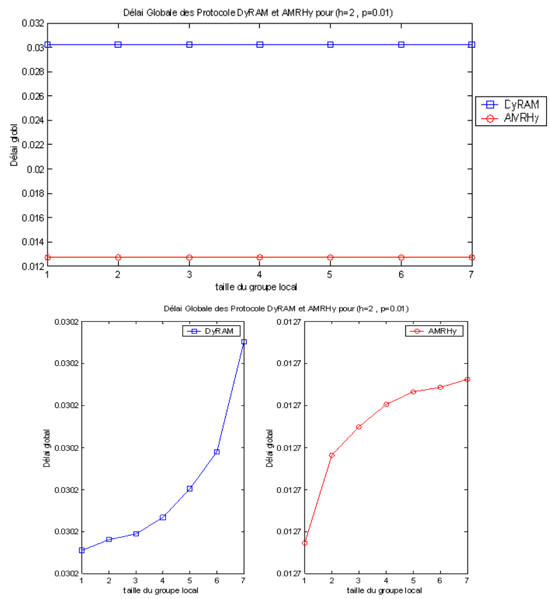

Fig. 8. Overall delay of the protocols A and D in function of the size of the local group (h = 2, p = 0.01)

5.2 Influence of the Depth of the Backbone H on the Overall Time

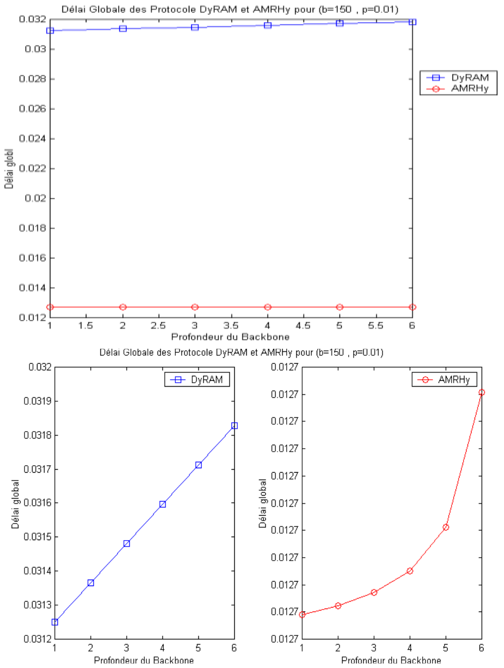

Fig. 9. Overall delay of the protocols A and D in function of the depth of the Backbone (B=150, p=0.1)

Fig. 9 show that the depth of the backbone affects the overall delay of both protocols **DyRAM** and **AMRHy**, the protocol **AMRHy** still more efficient compared to **DyRAM** for the same reason mentioned before. The figures also show that the depth of the backbone affects overall delays of both protocols **AMRHy** and **DyRAM**.

5.3 Influence of the Loss Probability P on the Overall Time

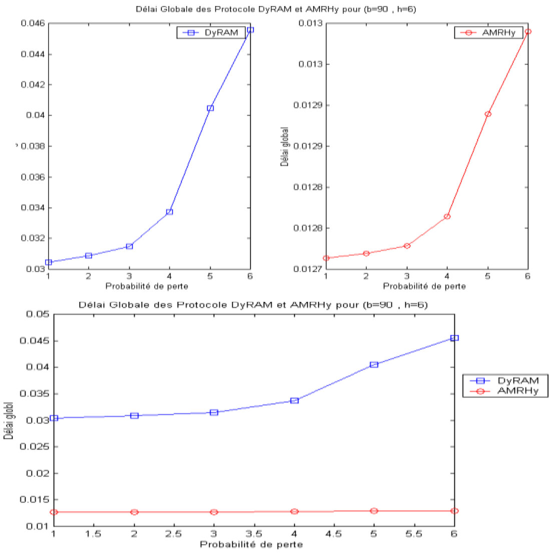

Fig 10: Overall delay of the protocols A and D in function of the loss probability (B=90, h=6)

Figure 10 show that the protocol **AMRHy** is more efficient than the protocol **DyRAM** in terms of overall delay thanks to the benefits of the aggregation and suppression of local ACKs service through a combination of both hierarchical and based on timers' approaches. These figures show that the probability of loss has a major influence on the overall delay in the protocol **DyRAM** This is due to the number of NAKs generated as many times as the packet is lost. The probability of loss also affects the protocol **AMRHy** but it is negligible compared to that protocol **DyRAM**.

6. Conclusion

This article was devoted to the comparative study of two protocols **AMRHy** and **DyRAM** with the analytical analysis. The results obtained show the exemplary behavior of the protocol **AMRHy** for environments highly unreliable transmissions with a dense population.

Indeed, it was observed that unlike the protocol **DyRAM**, delivery times in the protocol **AMRHy** are subject to a minimal degree of changes when the loss probability, the depth of the Backbone and the group size are increased.

Based on the results, one can conclude that the protocol **AMRHy** has the potential needed to migrate to a wireless environment (sensor networks, embedded systems, IoT, ect…). where the loss rate is too high . This potential can be summarized as:

- Simplicity of treatment
- Support for high loss rates
- Tolerance of a high density of receptors

As perspective, we will expand our analysis to the loss of acknowledgment (ACK and NAK) on the backbone.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.